Journal of Environmental Sciences Vol.13, No.2, pp.218—223, 2001

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2001)02-0218-06 **CLC number:** X52 **Document code:** A

Pollution of water resources due to industrialization in arid zone of Rajasthan, India

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Abstract: In arid zone of Rajasthan, India, nearly 21900 hm^2 area along Bandi River has been affected by industrial effluent discharge into the river bed. Analysis of groundwater samples collected from these sites revealed that area at the vicinity of the river is most affected. The effluent water in the river is the main source of contamination of ground water. Concentration of sodium and chloride has been higher with proportional increase in TDS and EC value in the area within zone A (river water), zone B (0 – 100m), zone C (101 – 250m), zone D (251 – 500m) and zone E (501 1000m). There is decreasing trend in ion concentration from zone A to zone E and F, reflecting reduced effect of effluents. The pollution of water resources has resulted in the degradation of other natural resources such as land, soil and vegetation. Nearly 4463 hm^2 (20.38%) area has been very severely affected. EC value at places exceeds 20 dS/m. Soil and land have become hard, compact and saline. Cropping intensity has declined. In the area (3633 hm^2) affected severely, the EC value of water varies from 10 ~ 20 dS/m. Irrigation with such water has created problem of salinity, sodicity in soils. Herbal biomass declined considerably. Double cropping has almost stopped. Almost 8494 hm^2 area is affected moderately. EC of ground water varies from 5 to 10 dS/m. Fragile surface crust, declining trend of phosphorous and potassium in the soil, poor density of natural vegetation are significant manifestations. Apart from this, 5305 hm^2 area is slightly affected.

Key words: pollution; water resources; industrialization; arid zone; India

Introduction

Urbanization and industrialization, the keys to development, have distorted environment and the intensity of this distortion was felt when it exceeded the limit beyond which it became irreparable. Water, the greatest solvent, has many roles to play in both urban and industrial development. Therefore, water pollution is the major indicator of environmental degradation. Riverbed, the biggest source of water, has been the convenient dumps for urban and industrial wastes, therefore causing pollution and ultimate degradation of water resource (Moharana, 1998). About 70 per cent of all available water in India is polluted (NEERI, 1993). Major industries, like iron and steel, textile and chemicals, paper and leather have been set up on the banks of major rivers. The waste discharged untreated into the river courses from these industries, ultimately cause water pollution and degrade both surface and ground water. India's perennial rivers like the Ganga, the Yamuna, the Hooghly have been officially acclaimed as most polluted rivers, reflects the more serious conditions of non-perennial rivers in India particularly in arid Rajasthan. According to CPCB (CPCB, 1990) report nearly 1000 textile units have grown up along the banks of three major ephemeral rivers in arid zone of Rajasthan, the Luni in Barmer district, the Bandi in Pali and the Jojri in Jodhpur district. All these industries discharge huge quantity of toxic wastes into these rivers and cause pollution (CAZRI, 1997). The present paper deals with the extent and severity of pollution of water resources along Bandi River of Guhiya basin which has resulted environmental degradation.

1 Location and the environment

The study area (21900 hm^2) along the Bandi River in Pali district is located between latitude 25°44′42″ to 25°54′50″N and longitude 72°46′20″ to 73°22′25″E between Nayagaon in the east and Dundara in the west with the altitude varying from 221 to 156m above mean sea level and covers 67 km in length. The major landform along this length of river are rocky/gravely pediment, flat older alluvial plains, younger alluvial plains and river bed. The mean annual rainfall of this region is 424 mm with 16 average number of rainy days. The relative coefficient of variation of annual rainfall is 45 per cent and standard deviation is 189.9 mm. The mean maximum and minimum temperature during summer season are 43℃ and 26.5℃, respectively which sometimes goes up to 47℃. During winter season the mean maximum and minimum temperture are 24.2℃ and 6℃ which may come down to 0℃. The mean relative humidity varies from 19 per cent in February to 82 per cent during August. The average wind speed is 8 km/h.

2 Procedure

Geocoded False Colour Composit (FCC) of Indian Remote Sensing LISS II imagery of April 1995 on 1:50000 scale were visually interpreted and the boundaries of effluent polluted units were transferred on Survey of India Topographical sheet at 1:50000 scale. These units, their boundaries and extent of area affected by industrial effluent under these units were checked in the field. Water samples from river bed and from key wells situated in the affected

area were collected in one liter polyethylene bottles and analyzed in the laboratory to determine the presence of chemical concentration in water. Based on the presence of chemical constituents and heavy metals, the severity of degradation were identified, delineated and mapped.

3 Source of industrial effluent

The point source of pollution is the discharge of domestic and industrial effluent. The waste water generated from 762 textile industrial complex is the main industrial effluent (Kumar, 1997). Processwise industrial units are (1) bleaching and causticizing; (2) dyeing; (3) screen printing; (4) finishing; (5) composing, bleaching, causticizing and printing (Table 1). In processing various chemicals mainly the carbonate, hydroxide, chloride, sulphate, sulphate oxychloride, nitrate and silicate of sodium, sulfuric acid, hydrogen peroxide, bleaching powder, acetic acid, detergent, dyes, gums and starch are used extensively (Table 2). The textile industries generate 36 million liters per day (MLD) which are susceptible with pH, alkalinity, chemical oxide demand (COD), biochemical oxide demand (BOD), total dissolved solids (TDS), total soluble solids (TSS) and other chemical constituents (NEERI, 1993). The characteristics of waste water generated in different processes in the textile processing units are presented in Table 3.

Table 1 Processwise distribution of industrial units

Process operations carried out by textile units	No. of units
Bleaching and causticizing	100
Dyeing	80
Screen printing	395
Finishing (calendering and dyeing)	150
Composing units (dyeing and printing only)	30
Bleaching, causticizing and printing	12
Total	767

Table 2 Chemicals used in various textile process operations

S.No.	Process	Chemical used
1	Causticizing	Caustic dye (sodium hydroxide)
2	Kiering/ Bleaching	Bleaching powder, sodium hypochlorite, O. T. wetting agent, tinopal or whitening agent etc.
3	Printing/ Dyeing	Azo dyes, direct dyes, reactive dyes, sulphur dyes etc.
4	Finishing	Sodium silicate (used for fixation of reactive dyes after printing

Table 3 Characteristics of wastewater generated from different activities in textile processing industries

S. N.	Activity	Colour	pH	Total alkalinity, (as $CaCO_3$), mg/L	TDS, mg/L	SS, mg/L	COD, mg/L	BOD, mg/L
1	Bleaching and causcitizing	–	9.0 – 11.5	3200 – 9000	3000 – 11500	500 – 1000	400 – 2000	50 – 300
2	Bleaching, causcitizing and printing	Light	10.0 – 11.5	2800 – 8500	3500 – 10500	800 – 1400	900 – 2000	100 – 300
3	Bleaching, causticizing and dyeing	Dark	9.0 – 11.5	1700 – 4800	3500 – 11000	400 – 950	400 – 1400	70 – 220
4	Bleaching, causticizing, dyeing and printing	Dark	10.4 – 11.5	1600 – 4500	3000 – 10000	400 – 1100	1000 – 5000	100 – 800
5	Causticizing and dyeing	Dark	10.6 – 11.5	10000 – 22000	20000 – 22000	400 – 1100	2000 – 3000	300 – 500
6	Causticizing and printing	Light	9.8 – 11.0	4000 – 10000	18000 – 20000	1000 – 2000	1500 – 2500	250 – 400
7	Causticizing dyeing and printing	Dark	10.0 – 11.0	16000 – 18000	18000 – 22000	800 – 2000	1800 – 2500	250 – 450
8	Dyeing	Dark	9.0 – 11.0	1800 – 10000	3000 – 8000	100 – 200	300 – 400	50 – 100
9	Printing	Light	7.0 – 9.5	400 – 600	5000 – 12000	300 – 1800	1000 – 2000	180 – 400
10	Dyeing and printing	Dark	8.0 – 10.5	2000 – 8000	4000 – 10000	700 – 1500	400 – 1600	50 – 300

4 Impact of industrial effluent on water resources

4.1 Depth to water

The depth to water in wells located in the river bed was almost the same as the level of water in the river. This is due to continuous replenishment of groundwater from the river. The depth to water in wells located at 0 – 100m distance from the river banks ranges from 0.2 – 6.1m below ground level (bgl). Depth to water in the wells located at 101 – 250m, 251 – 500m, 501 – 1000m, 1001 – 2000m and more than 2000m distance from river banks ranges from 2.1 – 8.8m, 1.5 – 8.9m, 1.6 – 16.7m, 2.8 – 14.5m and 1.5 – 15.2m bgl, respectively (Table 4). This indicates that these wells get recharge from the Bandi River at the varying rate. The seasonal variability in water level

Table 4 Distance of the wells from the river banks and their depth to water

Distance, m	Depth to water, bgl	
Av. depth	Range, m	Range, m
0 – 100	3.07	0.2 – 6.0
101 – 250	4.01	2.1 – 8.8
251 – 500	4.93	1.5 – 8.9
501 – 1000	5.80	1.6 – 16.7
1001 – 2000	3.77	2.8 – 14.5
>2000	4.90	1.5 – 15.2

in wells has been observed during pre and post monsoonperiod. After the rains there was significant increase in water level in wells due to availability of more water in river for replenishing the ground water in its vicinity. It has been observed that wells having depth to water more than 15m bgl are not affected by industrial effluent.

4.2 Physico-chemical characteristics of effluent polluted water

Analysis of data (Table 5) revealed that the polluted river water (zone A) is alkaline in nature and contains average EC 35.55 dS/m and TDS 22700 mg/L and is the principal source of groundwater pollution in the vicinity. As a result of discharge of industrial effluent from the river groundwater along its course starting from Pali upto Dundara Village have become highly polluted and, therefore, most of the wells have been abandoned. The average electrical conductivity (EC) and TDS of polluted ground water in wells in zone B (0 – 100m away from banks) are 15.79 dS/m and 10105 mg/L, respectively. Similarly the average concentration of sodium (Na) and chloride (Cl) which are the major constituents in polluted groundwater are 5099 and 1988 mg/L, respectively.

Table 5 Physico-chemical properties of groundwater in effluent affected wells along the river course

Zone	EC, dS/m	pH	TDS, mg/L	Cations, mg/L				Anions, mg/L			RSC, me/L	SAR	Na, %
				Ca	Mg	Na	K	CO_3	HCO_3	Cl			
A	35.54	7.9	22744	393	375	4991	16	120	366	10579	–	43.3	41.1
B	15.79	8.5	10105	68	277	5099	23	48	757	1988	9.2	59.6	94.7
C	9.98	8.6	6545	67	90	2914	14	107	851	2676	8.8	43.9	91.1
D	8.11	8.9	5189	40	73	2850	8	84	1110	1775	13.0	62.0	93.7
E	8.73	8.5	4566	176	121	2033	11	96	856	1739	3.0	39.0	84.9
F	6.57	8.4	4079	162	109	2482	11	42	412	1923	0.32	36.7	83.8

A: river water; B: wells located 0 – 100m away from river banks; C: wells located 101 – 250m away from river banks; D: wells located 251 – 500m away from river banks; E: wells located 501 – 1000m away from river banks; F: wells located > 1000m away river banks

Table 6 Impact of industrial effluent on groundwater quality at different sites along the Bandi River

Site	pH	EC, dS/m	Cation, mg/L				Anions, mg/L		RSC, me/L	SAR	Na, %	TDS, mg/L	Heavy metals, mg/L			
			Ca	Mg	Na	K	Cl	HCO_3					Cu	Fe	Zn	Mn
Sonji-ki -Dhani	8.7	3.80	40	49	1550	13	1349	537	–	39	91	2432	0.08	1.24	0.20	0.25
Pali	8.2	5.44	80	48	1399	17	1775	122	–	30	88	3480	0.02	1.26	0.15	0.15
Mandiya	8.6	8.71	40	73	2438	24	1689	366	2.0	53	92	5576	0.02	1.21	0.17	0.18
Kerla	8.8	8.96	56	49	2549	25	2840	329	2.2	61	94	5736	0.02	1.21	0.16	0.18
Garwara	9.1	5.98	56	15	1900	53	1278	1293	–	58	94	3828	0.03	1.09	0.15	0.25
Phekariya	8.7	5.90	49	44	1599	31	1988	610	4.0	40	91	3775	NA	NA	NA	NA
Dundara	9.1	4.23	24	20	1250	49	1420	1135	–	56	93	2705	NA	NA	NA	NA
Rampura	9.2	4.60	22	15	1749	50	1447	1538		48	97	2944	NA	NA	NA	NA

NA: not available

EC in groundwater in some of the wells in zone C (101 – 250m away from the banks) is as high as 26.54 dS/m. In general the average EC and TDS in groundwater in this zone are 9.98 dS/m and 6545 mg/L, respectively. Concentration of sodium and chloride is also very high and ranges from 949.9 to 8280 and 852 to 6603 mg/L, respectively. The pH values in all the wells are more than 8. Similarly sodium percentage in groundwater in all the wells in this zone is more than 86 indicating that water is not suitable for irrigation or for drinking purposes.

Ionic concentration in groundwater has decreasing trend in the wells located away from the river banks. In zone D (251 – 500m away from the banks) and zone E (501 – 1000m away from the banks) the average concentration of EC in groundwater is 8.11 and 8.73 dS/m and TDS is 5189 and 4566 mg/L, respectively. Similarly the average concentration of Na and Cl in zone D are 2850 and 2033 mg/L, whereas, in zone E they are 1775 and 1739 mg/L, respectively. Constituents of other ionic concentration such as Ca, Mg and K have followed similar trend.

Some of the wells located in the zone F (1001 to 2000m away from the banks) have also the impact of pollution

from the river water. This is quite distinct in a well located in Pali Town 1.5km away from the left bank of the river with EC of 11.39 dS/m. Similar condition has been noticed in a well located at village Phekariya which contains EC more than 13 dS/m. The average concentration of EC and TDS in this zone are 6.57 dS/m and 4079 mg/L, respectively. The polluted wells water are not suitable either for irrigation or drinking purpose.

Water pollution in the river system in the study area has increasing trend downstream upto Kerla Village (Table 6). In case of conductivity and TDS of polluted river water collected from the vicinity of Sonji-ki-Dhani, Pali Town and Mandiya and Kerla villages were 3.80, 5.44, 8.71 and 8.98 dS/m and 2432, 3480, 5576 and 5736 mg/L, respectively. Similar trend has been observed in the concentration of the sodium and chloride constituents. However, the concentration of conductivity, TDS, sodium and chloride has decreasing trend in river water down stream of Kerla Village. This may be the effect of dilution of polluted river water due to rain runoff water as the water samples were collected just after the 1996 monsoon period.

Temporal and spatial variability in groundwater quality in effluent affected area is very high (Fig.1). Previous data of some of the wells available with Rajasthan ground Board, Jodhpur was compared with the present status. It has been observed that TDS in a well at village Sukarlai during 1965, when industrialization process started was 2200 mg/L and with the discharge of industrial effluent concentration increased to 14800 during 1980 and more than 22000 during 1996. Similar trend followed in wells located in Garwara Village. The sharp increase in TDS at Pali was after 1980. However, at Nayagaon and Phekariya the increase was after 1985 when the effluent travelled further down reach. This shows that the deterioration in groundwater in the last 30 years is very high when TDS increased many fold. With irrigation from polluted well water the natural resources have severely degraded resulting overall environmental degradation.

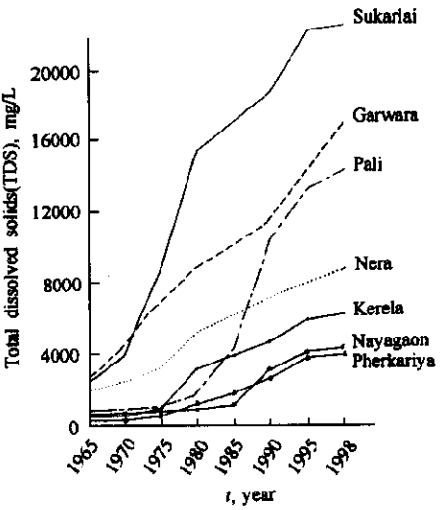

Fig.1 Temporal and spatial increase in total dissolved solids in groundwater due to industrial effluent pollution

The presence of heavy metals in the polluted groundwater is not significantly high. Concentration of copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn) in all the six zones ranges from 0.02 to 0.37, 0.94 to 1.66, 0.14 to 0.25 and 0.02 to 0.37 mg/L, respectively (Table 7).

Table 7 Presence of heavy metals in groundwater of the effluent affected wells along the river course

Zone	Cu, mg/L	Fe, mg/L	Zn, mg/L	Mn, mg/L
A	0.05(0.02-0.08)	1.15(1.08-1.26)	0.17(0.15-0.20)	0.20(0.15-0.25)
B	0.14(0.09-0.23)	1.07(0.94-1.18)	0.19(0.17-0.23)	0.30(0.23-0.37)
C	0.11(0.10-0.12)	1.34(1.10-1.66)	0.24(0.23-0.25)	0.18(0.02-0.34)
D	0.15(0.03-0.37)	1.26(1.10-1.51)	0.21(0.19-0.25)	0.19(0.08-0.25)
E	0.04(0.03-0.05)	1.30(1.14-1.46)	0.18(0.14-0.22)	0.12(0.09-0.16)

A: River water; B: wells located 0-100m away from river banks; C: wells located 101-250m away from river banks; D: wells located 251-500m away from river banks; E: wells located 501-1000m way from river banks; F: wells locate d>1000m away from banks

5 Severity of environmental degradation due to water resources pollution

Discharge of untreated industrial effluent in open drains and river system in the study area has created serious environmental problem due to degradation of natural resources in large tract. Degradation of natural resources has been classified as very severe, severe, moderate and slight (Fig.2).

5.1 Very severe

Out of the total 21900 hm^2 degraded area, nearly 4463 hm^2 (20.38%) has been very severely affected by the industrial effluent. Such lands cover entire industrial areas which further extend along the river between Mandiya, Giradara, Muliyawas, Sukarlai and Jetpur and between Dholeriya and Nera towards its left bank and around Jawariya, Kerla, Chatelav and Garwara villages towards the right bank. The ground water in this zone has EC values between 10 to 20 dS/m which at places exceeds 20 dS/m. Moreover, sodium percentage and SAR are also high. Due to stagnation of effluent water, the soils in the affected area around Pali Town have undergone substantial

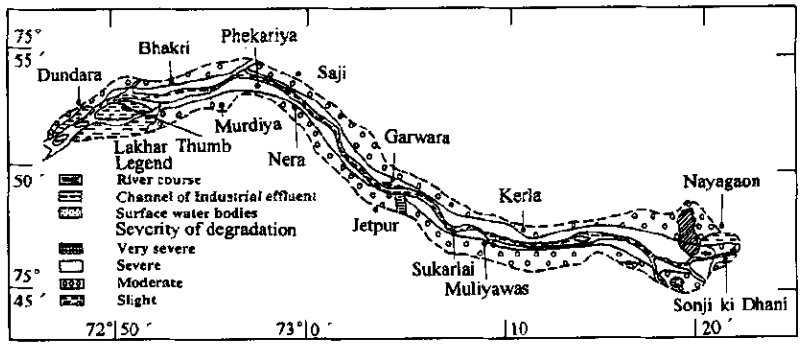

Fig.2 Impact of industrial effluent on water resources

morphological changes and also have became hard and compact. Along the river, salt crust on the soils surface developed and they become hard and compact. The soils became highly saline (EC 5.5 – 54.6 dS/m) in the depletion of their productivity. The organic carbon and available phosphorus in the soils also declined leading to nutrients deficiency. The morphological properties of the landforms also changed due to formation of surface crust and cavities in rocks. However, very severe impact of effluent on vegetation could not be observed. In irrigated crop lands, the cropping intensity, crop yield and crop residue declined up to 75 per cent while at some places the cultivation is completely stopped.

5.2 Severe

Severely affected area due to industrial effluent constitutes 3633 hm^2(16.59%) and occur dominantly along the right banks of the river in a narrow strip of half to one km wide between Pali and Dundara, whereas, on the left bank of the river the affected areas are encountered around Mandiya, Muliyawas, Sukarlai and west of Jetpura villages. Severely affected groundwater in this zone has EC between 10 to 20 dS/m and nearly 14.29 per cent wells covering an area of 6523 hm^2(29.79%) fall under this category. Due to irrigation with polluted groundwater, the salinity and sedicity conditions are developed in the soils and consequently their morphology has also changed. The EC, pH, SAR and ESP values have increased manifold. The soils have become hard and compact leading to low infiltration rate, decline in organic carbon and available phosphorous. Morphological properties and biological potentials of the landforms have also been severely affected due to formation of surface crust. In natural vegetation, the density of plants and number of species declined to a greater extent. Herbage bio-mass declined from 404 kg/hm^2 to 101 kg/hm^2. Due to stagnation of effluent on scrub lands and pastures, discoloration and deformation on 5 per cent leaf-stem has taken place. In irrigated crop lands, the cropping intensity, crop productivity and production of cropresidues declined by 51 to 75 per cent. Double cropping has almost stopped.

5.3 Moderate

Moderately affected area constitutes 8494 hm^2(38.81%) and they occur on both sides of the river course. In the left bank of the river such areas are concentrated one to one and half km away adjacent to the severely affected area located between Pali and Dholeriya and thereafter it runs along the river bank. The moderately affected areas on the right bank also occur upto a distance of 0.5 to 1.5 km away from the river bank at lower reach of Guhiya River. The ground water falling under this category of severity of degradation, has EC between 5 to 10 dS/m and occurs in the largest area (60.22%). The soils and landforms are also affected by this category of degradation. In river bed, the color of the riverine deposits has become greenish and weak and fragile surface crust has developed. The pH of the affected soils has increased ranging from 8.0 to 9.7. The organic carbon and available phosphorus and available potassium of the affected soils are also declined. Natural vegetation was affected all along the river bank as indicated by poor density, discoloration and deformities of Tamarix aphella. In the irrigated cropped land the cropping intensity, crop productivity and the production of crop residue declined between 26 to 50 per cent. In rained cropped lands, the crop productivity and cropping intensity declined between 15 to 25 per cent.

5.4 Slight

Slightly affected area constitutes 5305 hm^2(24.22%) and occurs in a narrow strip along the boarder line of this area. Such affected lands are largely concentrated near Murdia, Bhakri, Dewandki, Samuja, Sonji-ki-Dhani and north-west of Pali. The ground water is slightly affected as indicated by EC values below 10 dS/m. Soils have low salinity and moderate seduced development trend. At some places no specific soil degradation has been taken place in soils condition. Most of these lands are under rainfed farming and located away from the river bank hence the impact

of the industrial effluent on the natural vegetation as well as on the present landuse is limited and there is no visible impact of effluent on these resources. But in the near future, these lands are likely to be affected if this hazard is not tackled properly.

6 Conclusion

The environmental degradation in Pali District in western Rajasthan, India is the outcome of discharge of huge quantity of toxic wastes into the Bandi River system from 767 textile units. The discharge of untreated industrial effluent in river system has polluted water resources in near vicinity. Such water pollution has affected other natural resources, predominantly the land, soils, vegetation and the existing crop potentiality. If the present trend is continue more and more area will be affected with environmental degradation.

Acknowledgement: Authors wish to thank Director, Central Arid Zone Research Institute, Jodhpur for providing facilities and encouragement during course of this study.

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(Received for review February 15, 2000. Accepted May 20, 2000)